

FD-302 (Rev. 4-15-64)

GEO-ATMOSPHERICS CORP LINCOLN MA F/O 4/2
CLOUD/ICING/VISIBILITY ANALYSIS SYSTEM (CIVAS) AND FORECAST DEV--ETC(U)
APR 80 W D MOUNT; B R FOW; B D MOUNT DAAD07-79-C-0089

ERADCOM/ASL-CR-80-0089-1 NL

UNCLASSIFIED

$$E_1 \otimes_{\mathbb{Q}} \mathbb{C} = \mathbb{C}(t)$$

END
DATE
FILMED
7-80
DTIC

ADA 085530

ASL-CR-80-0089-1

ERADCOM/ASL

LEVEL

AD

Reports Control Symbol
OSD-1366

6 CLOUD/ICING/VISIBILITY ANALYSIS SYSTEM (CIVAS)
AND FORECAST DEVELOPMENT PLAN

APR 1980

Prepared by

10 WAYNE D. MOUNT
B. RICHARD FOW
BRUCE D. MOUNT

Geo-Atmospherics Corporation
Box 177
Lincoln, Massachusetts 01773

DTIC
ELECTE
JUN 16 1980

15 Under Contract: DAAD07-79-C-0089

Contract Monitor: HARRY MAYNARD

16 1112211471

Approved for public release; distribution unlimited



US Army Electronics Research and Development Command
ATMOSPHERIC SCIENCES LABORATORY
White Sands Missile Range, NM 88002

392935
80 6 13 002

NOTICES

Disclaimers

The findings in this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

The citation of trade names and names of manufacturers in this report is not to be construed as official Government indorsement or approval of commercial products or services referenced herein.

Disposition

Destroy this report when it is no longer needed. Do not return it to the originator.

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ASL-CR-80-0089-1	2. GOVT ACCESSION NO. AD-A085530	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) CLOUD/ICING/VISIBILITY ANALYSIS SYSTEM (CIVAS) AND FORECAST DEVELOPMENT PLAN	5. TYPE OF REPORT & PERIOD COVERED Technical Report	
7. AUTHOR(s) Wayne D. Mount, B. Richard Fow, and Bruce D. Mount	6. PERFORMING ORG. REPORT NUMBER	
9. PERFORMING ORGANIZATION NAME AND ADDRESS Geo-Atmospherics Corporation Box 177 Lincoln, MASS 01773	8. CONTRACT OR GRANT NUMBER(s) DAAD07-79-C-0089	
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Electronics Research and Development Command Adelphi, MD 20783	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 1L162111AH71	
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Atmospheric Sciences Laboratory White Sands Missile Range, NM 88002	12. REPORT DATE April 1980	
	13. NUMBER OF PAGES 68	
	15. SECURITY CLASS. (of this report) UNCLASSIFIED	
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES Contract Monitor: Harry Maynard		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Aviation weather Aircraft icing Clouds Icing forecasts Visibility Computer programs		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Geo-Atmospherics Corporation previously developed atmospheric models, meteorological data interpretation techniques, and computer software to provide a Cloud/Fog/Analysis System (CFAS) and Cloud/Fog Application Routines (CFAR). The CFAS assimilates the four-dimensional distribution of weather information by taking into account type, age, and location of meteorological observations to perform an objective analysis to specify each weather variable on a moveable three-dimensional array of grid points. This data base generated by CFAS can		

20. ABSTRACT (Cont)

be used individually or its parts analyzed to tailor operational products to a given application. Our CFAR was developed to interrogate the CFAS data base, extract, analyze, and display a map of each chosen parameter, i.e., skv cover, ceiling, visibility, precipitation, severe weather, cloud base, cloud top, and cloud amounts within nine different layers extending from the surface to 3000 meter altitude, the highest level of interest to Army aviation. These techniques have been expanded to develop a Cloud/Icing/Visibility Analysis System (CIVAS) to deduce the three-dimensional distribution of clouds, aircraft icing threat, and visibility, on a horizontal grid scale of 5 km.

The first part of this effort was to "prepare an outline plan for a program to develop the capability to forecast the CIVAS weather parameters (clouds, freezing level, visibility, etc.) up to twelve hours in advance. This plan shall include a time schedule and estimate of resources required." The first sections of this report contain our viewgraphs used, in an oral briefing of Army Atmospheric Science Laboratory personnel, to outline a plan to develop a CIVAS forecast capability. Four separate, but interrelated, work phases extending over a three-year time span were outlined. The first phase deals with developing and verifying cloud models that depict meso and micro scale synoptic climatology of aircraft icing features. Forecasting aspects were treated separately depending upon the forecast time interval. One program draws heavily upon real time objective analysis parameters to formulate nowcasting methods to meet short term (0-9 hours) user icing requirements. Another program combines objective analysis techniques with meso scale dynamical prediction models to satisfy the medium term (6-12 hours) aircraft icing forecast needs. The last phase outlines a plan of action needed to establish an in-field demonstration of CIVAS operational utility. Primary attention was given to a European theater analysis and forecast technique development plan dealing with occurrence, horizontal and vertical location, type, and intensity of aircraft icing.

The last section of this report describes changes and additions we made to our CFAS and CFAR to develop an objective analysis technique to provide CIVAS (Cloud/Icing/Visibility Analysis System). Icing models were formulated, fine mesh grid patterns were generated for initial analyses and output displays, and computer programs were written and checked out on one meteorological data set to establish an initial feasibility of CIVAS analyses for southeastern USA.

Accession For	
NTIS GRA&I	☒
EDC TAB	☐
Unannounced	☐
Justification	
By	
Distribution/	
Availability Codes	
Dist.	Avail and/or special
A	

TABLE OF CONTENTS

<u>Title</u>	<u>Page</u>
1. INTRODUCTION AND OVERVIEW	1
EFFECTS OF ICE ON AIRCRAFT	6
AIRCRAFT ICING TYPE	7
RATE OF ICE ACCRETION	8
SOME GENERAL COMMENTS ON ICING SITUATIONS	9
SOME METEOROLOGICAL PARAMETERS IMPORTANT TO AIRCRAFT ICING	10
2. DEVELOPMENT PLAN FOR CIVAS FORECASTS (0-12 HRS)	11
PHASE I - CLOUD ICING MODELS	12
PHASE II - SHORT TERM (0-9 HRS) NOWCASTING	13
PHASE III - MEDIUM TERM (6-12 HRS) DYNAMIC FORECASTING	14
PHASE IV - ICING FORECAST DEMONSTRATION DATA SYSTEM	15
PHASE I - CLOUD ICING MODELS	
Task 1 - Develop Meteorological Icing Event Profiles	16
Task 2 - Derive Synoptic Climatology	17
Task 3 - Develop Cloud Physics Specification Techniques	18

TABLE OF CONTENTS (Continued)

<u>Title</u>	<u>Page</u>
Task 4 - Conduct Verification Studies	19
PHASE II - SHORT TERM (0-9 HRS) NOWCASTING	
Task 1 - Develop CIVAS Kinematic Forecast Techniques	20
Task 2 - Implement Real-Time CIVAS Operations	21
Task 3 - Incorporate New Cloud Icing Models in CIVAS	22
Task 4 - Conduct In-Field CIVAS European Demo	23
PHASE III - MEDIUM TERM (6-12 HRS) DYNAMIC FORECASTING	
Task 1 - Formulate Analysis Techniques Suitable for Dynamic Forecasting	24
Task 2 - Combine CIVAS with Macro and Meso-Scale Dynamic Forecast Models	25
Task 3 - Conduct Experimental Validation Studies	26
PHASE IV - ICING FORECAST DEMONSTRATION DATA SYSTEM	
Task 1 - Prepare Experimental Designs for Field Demonstrations	27
Task 2 - Establish Grid Networks and Data Gathering Procedures	28

TABLE OF CONTENTS (Continued)

<u>Title</u>	<u>Page</u>
Task 3 - Develop Data Base Management System	29
Task 4 - Complete Computer Graphics Output and Verification Programs	30
CIVAS FORECAST PLAN	31
3. CIVAS DESCRIPTION	32
3.1 BACKGROUND	32
3.2 DEVELOPMENT OF CIVAS FROM CFAS	40
3.2.1 <u>Icing Information Content in the Existing Input and Output Data of the CFAS</u>	41
3.2.2 <u>Determination of Probability and Type of Icing</u>	42
3.2.3 <u>Two Stage Icing Model Implementation</u>	44
3.2.4 <u>Five Kilometer Grid Interpolation</u>	50
4. DESCRIPTION OF CIVAS PROGRAMS	53
4.1 CFAS ROUTINES MODIFIED FOR CIVAS	53
4.1.1 <u>Subprogram BASE</u>	53
4.1.2 <u>Subprogram BEGIN</u>	53
4.1.3 <u>Main Program CFMAIN/DSK</u>	53
4.1.4 <u>Subprogram CFMAP</u>	53
4.1.5 <u>Subprogram COMOBR</u>	54

TABLE OF CONTENTS (Continued)

<u>Title</u>	<u>Page</u>
4.1.6 <u>Subprogram EXEC1</u>	54
4.1.7 <u>Subprogram EXEC2</u>	54
4.1.8 <u>Subprogram RAOB</u>	55
4.1.9 <u>Subprogram RETOBR</u>	55
4.1.10 <u>Subprogram SFDINT</u>	56
4.1.11 <u>Subprogram UADINT</u>	56
4.2 NEWLY CREATED ROUTINES FOR CIVAS	57
4.2.1 <u>Subprogram ADJUST</u>	57
4.2.2 <u>Subprogram CONVERT</u>	57
4.2.3 <u>Subprogram EXPAND</u>	58
4.2.4 <u>Subprogram ICING</u>	59
4.2.5 <u>Subprogram LSTMAP</u>	61
4.2.6 <u>Subprogram REREF</u>	62
4.2.7 <u>Subprogram WETHER</u>	62
5. REFERENCES	63

1. INTRODUCTION AND OVERVIEW

Aircraft icing effects both fixed wing and rotor type craft whenever supercooled water droplets (cloud or precipitation) are encountered. Hazardous icing conditions develop whenever the airfoil shape is distorted (caused mostly by rime ice), the aircraft's weight is significantly increased (caused mostly by clear ice), the control surfaces are inhibited in their use, the propellers or rotors vibrate excessively due to an unbalanced ice load, and/or the engine air intakes are blocked. Aircraft icing varies considerably in density, transparency, and hardness; and these variations are controlled by temperature, drop size, liquid water content, rate of accretion, and exposure time in the icing medium. Factors which favor clear ice (or glaze) formation are large drop size, rapid accretion of liquid water, slight supercooling, and slow dissipation of latent heat of fusion. This relatively transparent clear ice produces homogeneous layers which have a small number and size of air pockets in the ice. Aircraft flights through supercooled droplet regions at an air temperature between 0° to -40°C are most conducive to clear icing. Rime ice formation, on the other hand, is favored by small drop size, slow accretion, a high degree of supercooling, and rapid dissipation of latent heat of fusion.

which is found when one particle freezes before the next one strikes. Flights through highly supercooled clouds (-10°C or colder) are very conducive to rime icing. The ideal rime ice is characterized by what is called kernel ice (-15°C or colder), whereas that intermediate between rime and clear ice is called milky ice (-4° to -15°C). Thus, by knowing air temperature of supercooled clouds it is possible to infer aircraft icing type.

Water droplet sizes and number concentrations vary considerably depending upon such things as cloud type, rain intensity, geographical locations, and season. Also, relations need to be developed to infer supercooled liquid water amounts as a function of height, temperature, and type of clouds. By combining information on water drop sizes and concentrations with available supercooled liquid water content it is possible to develop categories which resolve aircraft icing as being low, moderate, or heavy in intensity. Aircraft icing intensity was not included in the initial CIVAS analysis portion of this study but was addressed in the plan for future CIVAS development.

There were two parts to this study dealing with aircraft icing. The study itself was labeled CIVAS (Cloud/Icing/Visibility Analysis System). The first part developed a plan of action needed to implement a nowcasting (0 to 9 hours) and a dynamic forecasting (6 to 12 hours) capability for aircraft icing. The second part was an engineering approach to take the first step in extending our existing objective analysis techniques to specify

a measure of probability, type and location of aircraft icing.

The first part of our CIVAS effort was to "prepare an outline plan for a program to develop the capability to forecast the CIVAS weather parameters (clouds, freezing level, visibility, etc.) up to twelve hours in advance. This plan shall include a time schedule and estimate of resources required." This final report contains our viewgraphs, used in an oral briefing of Army Atmospheric Science Laboratory personnel, outlining a plan to develop CIVAS forecast capability. Primary attention was directed to a European theater analysis and forecast technique development plan dealing with occurrence, horizontal and vertical location, type, and intensity of aircraft icing.

The development plan for forecasting CIVAS parameters up to twelve hours in advance was outlined in four major program phases. Phase I discussed formulation and verification of cloud icing models and included studying actual icing event profiles, deriving synoptic climatological characteristics, and specifying cloud microphysical features important to aircraft icing. Phase II and III dealt with two approaches to developing short range icing forecast techniques. Phase II described a kinematic approach that could be implemented immediately but was expected to be effective for only the zero to nine hour forecast time period. Phase III described a dynamical forecast approach that would be effective during a six to twelve hour forecast time period but would best be implemented by drawing upon the results from existing research meso scale forecast models. Phase IV outlined data gathering, processing, and displaying programs that

would be common to either the nowcast or the dynamic forecast approach and that would be needed to demonstrate real time operational utility of aircraft icing forecasts in Europe.

Estimates were made for labor, computer, and other resources required to carry out each task within each phase. The number of man months of work was given for each labor category and transferred into a total labor dollar amount by assuming reasonable values for overhead, general and administrative, and fee expenses. All computer time estimates were made with respect to using the Univac 1108 computer at White Sands Missile Range. An estimate was made for the total number of consecutive months needed to complete the effort required within each task. The last viewgraph provided a composite of the dollar amount and time schedule required for each task, assuming a sequential implementation of each phase. More than a three year effort was outlined at a grand total cost of \$601,000. Some phases of the program could be treated separately while others are highly interdependent and can not stand alone. All resource and time estimates were purposely made tight with the expectation being that an engineering rather than a research approach would be taken to expedite and establish a European demonstration of the forecast capability of CIVAS for aircraft icing.

The second part of our study was an engineering development of a Cloud/Icing/Visibility Analysis System (CIVAS) to deduce the three-dimensional distribution of cloud, aircraft icing threat, and visibility on

a horizontal grid scale of 5 km. The CIVAS work draws heavily upon our previously developed atmospheric models, meteorological data interpretation techniques, and computer software to provide a Cloud/Fog Analysis System (CFAS) and Cloud/Fog Application Routines (CFAR). The CFAS assimilates the four-dimensional distribution of weather information by taking into account type, age, and location of meteorological observations to perform an objective analysis to specify each weather variable on a moveable three-dimensional array of grid points. This data base generated by CFAS can be used individually or its parts analyzed to tailor operational products to a given application. Our CFAR was developed to interrogate the CFAS data base, extract, analyze and display a map of each chosen parameter, i.e. sky cover, ceiling, visibility, precipitation, severe weather, cloud base, cloud top, and cloud amounts within nine different layers extending from the surface to 3,000 meter altitude, the highest level of interest to Army aviation. Our approach to the engineering CIVAS computer program was designed to automatically and objectively analyze the initial state of the atmosphere to specify the probability, type, and location of aircraft icing. In order to demonstrate initial feasibility with a minimum of effort, CIVAS analyses were made for the same time and geographical (Alabama) locations as previously used with CFAS. The results show that it is possible to extend these techniques to other geographical locations to routinely and automatically depict discrete atmospheric layers and geographical locations where a threat of aircraft icing exists.

EFFECTS OF ICE ON AIRCRAFT

1. PROPELLER OR ROTOR ICING
 - (a) Loss of propeller efficiency
 - (b) Vibration
2. ICE ON WINGS AND EXPOSED SURFACES
 - (a) Loss of lift
 - (b) Added drag
 - (c) Added weight
3. FREEZING OF CONTROLS
4. ICING OF PITOT TUBES AND CARBURATOR
5. WINDSHIELD ICING

AIRCRAFT ICING TYPE

1. Clear ice (glaze) (0 to -4C)
2. Milky ice (rime) (0 to -15C)
3. Frost (kernel) (colder than -15C)

RATE OF ICE ACCRETION

1. Size of cloud or rain droplets
2. Density of supercooled water droplets
3. Air speed
4. Shape of external area being impacted

SOME GENERAL COMMENTS ON ICING SITUATIONS

1. About 85% of observed aircraft icing in U.S.A. is associated with frontal zones.
2. Convective type clouds such as cumulus or active frontal clouds normally have larger cloud or rain droplets and are more likely to produce glaze icing at a high acceleration rate.
3. Stable type clouds such as fog and stratus usually have smaller droplets and are more likely to produce rime icing at slower acceleration rates.
4. Terrain induced upward motions on the windward side of ridges increase droplet sizes to enhance severe icing.

Some Meteorological Parameters Important to Aircraft Icing

1. Supercooled liquid water concentration in clouds or rain.
2. Cloud or rain drop size distribution and number concentration as a function of cloud type, droplet temperature, location, season, and precipitation type and intensity.
3. Ambient air temperature and moisture profile.
4. Cloud base height and temperature and horizontal and vertical extent of cloud.
5. Cloud type (liquid water content in cumulus is twice that in stratus which is twice that in alto-type clouds).
6. Lifting condensation or differential advection or horizontal convergence producing clouds.
7. Formation of ice crystals in cloud causing nucleation of supercooled droplets and greatly reducing icing hazard.

2. DEVELOPMENT PLAN FOR CIVAS FORECASTS (0-12 Hrs)

Phase I - Cloud Icing Models

Phase II - Short term (0-9 Hrs) Nowcasting

Phase III - Medium term (6-12 Hrs) Dynamic Forecasting

Phase IV - Icing Forecast Demonstration Data System

PHASE I - CLOUD ICING MODELS

Task 1 - Develop Meteorological Icing Event Profiles

Task 2 - Derive Synoptic Climatology

Task 3 - Develop Cloud Physics Specification Techniques

Task 4 - Conduct Verification Studies

PHASE II - SHORT TERM (0-9 Hrs) NOWCASTING

Task 1 - Develop CIVAS Kinematic Forecast Techniques

Task 2 - Implement Real-Time CIVAS Operations

Task 3 - Incorporate New Cloud Icing Models in CIVAS

Task 4 - Conduct In-Field CIVAS European Demo

PHASE III - MEDIUM TERM (6-12 Hrs) DYNAMIC FORECASTING

Task 1 - Formulate Analysis Techniques Suitable for Dynamic Forecasting

Task 2 - Combine CIVAS with Macro and Meso-Scale Dynamic Forecast Models

Task 3 - Conduct Experimental Validation Studies

PHASE IV - ICING FORECAST DEMONSTRATION DATA SYSTEM

Task 1 - Prepare Experimental Designs for Field Demonstrations

Task 2 - Establish Grid Networks and Data Gathering Procedures

Task 3 - Develop Data Base Management System

Task 4 - Complete Computer Graphics Output and Verification
Programs

PHASE 1 - CLOUD ICING MODELS

- Develop Meteorological Icing Event Profiles

Obtain listing of dates, location, time, and altitude with known helicopter icing in Europe.

Obtain corresponding weather data from surrounding stations. Analyze these data to obtain icing event profiles that describe meteorological conditions associated with occurrence, type, and severity of icing.

Resources:

Labor (months): Scientist 3

 Programmer 0

 Assistant 3

 Labor Cost \$34K

1108 Computer: None

Other: \$500 (Travel and Materials)

Performance Time: 5 Months

 Total \$34.5 K

PHASE I - CLOUD ICING MODELS

Task 2 - Derive Synoptic Climatology

Focus attention on synoptic weather patterns favorable for aircraft icing. Identify synoptic features typically associated with icing events and derive statistics to obtain probability of icing for given synoptic situations. Isolate seasonal, geographical, and terrain effects.

Resources:

Labor (months): Scientist 2

 Programmer 1

 Assistant 4

 Labor Cost \$33 K

1108 Computer: 1 Hour

Other: \$100

Performance Time: 4 Months

 Total \$33.1 K

PHASE I - CLOUD ICING MODELS

Task 3 - Develop Cloud Physics Specification Techniques

focus attention on most frequently occurring cloud types producing aircraft icing. Develop models to specify droplet size and number distribution as a function of cloud type, height, and thickness above the freezing level. Formulate procedures to calculate available liquid water content within supercooled portion of clouds.

Resources:

Labor (months):	Scientist	3
	Programmer	1
	Assistant	1

Labor Cost \$31 K

1108 Computer: 1/2 Hour

Other: None

Performance Time: 4 Months

Total \$31 K

PHASE I - CLOUD ICING MODELS

Task 4 - Conduct Verification Studies

Review literature and contact original investigators to obtain date, time, and location of in-situ cloud physics observations of cloud particle type, size and number distribution, and liquid water content. Apply cloud physics specification techniques to corresponding standard weather observations to infer cloud properties within the supercooled cloud regions. Verify inferred values against experimental in-situ cloud measurements. Assess feasibility and reliability of incorporating cloud physics specifications within CIVAS.

Resources:

Labor (months):	Scientist	2
	Programmer	2
	Assistant	3
	Labor Cost	\$34 K
1108 Computer:	2 Hours	
Other:	\$1500 (Travel and Materials)	
Performance Time:	5 Months	
	Total	\$35.5 K

PHASE II - SHORT TERM (0-9 Hrs) NOWCASTING

Task 1 - Develop CIVAS Kinematic Forecast Techniques

Study the time history of meteorological characteristics conducive to aircraft icing. Identify those characteristics having short term continuity in either horizontal or vertical displacement or both. Formulate objective methods for isolating key identifiable icing features. Develop kinematic techniques suitable for depicting these meteorological icing characteristics in time increments from zero to nine hours.

Resources:

Labor (months):	Scientist	3
	Programmer	2
	Assistant	1
	Labor Cost	\$35 K

1108 Computer: 1 Hour

Other: None

Performance Time: 4 Months

Total \$35 K

PHASE II - SHORT TERM (0-9 Hrs) NOWCASTING

133.0 - Implement Real-Time CIVAS Operations

Focus on developing CIVAS to provide an early demonstration of value in Europe. Identify geographical area encompassing data gathering versus data analysis regions. Compile all surface and upper air weather observing stations according to type, latitude and longitude, altitude above sea level, and derive UTM coordinates. Analyze station calling and coding sequence for European data gathering region and develop data assimilation programs. Develop data decoding and error checking sequences. Work with European weather communication specialists to establish data drops and computer interface programs. Work with Army personnel to establish on-site computer requirements, computer selection, implementation and check out, and off-site displaying of helicopter icing data.

Resources:

Labor (months):	Scientist	6	
	Programmer	12	
	Assistant	4	
	Labor Cost		\$109 K
1108 Computer:	15 Hours		
Other:	\$2,000 (Travel and Materials)		
Performance Time:	18 Months		\$111 K

PHASE II - SHORT TERM (0-9 Hrs) NOWCASTING

Task 3 - Incorporate New Cloud Icing Models in CIVAS

Study the results from the cloud physics and climatology modeling task and determine the impact areas within CIVAS. Prepare add-on flow diagrams to the CIVAS system to incorporate these cloud physics and climatology algorithms. Modify, extend, and program a new CIVAS system to incorporate detailed cloud icing models.

Resources:

Labor (months):	Scientist	1		
	Programmer	2		
	Assistant	0		
			Labor Cost	\$16 K
1108 Computer:	0			
Other:	0			
Performance Time:	2 Months			
			Total	\$16 K

PHASE II - SHORT TERM (0-9 Hrs) NOWCASTING

Task 4 - Conduct In-Field CIVAS European Demo

Conduct a two-month operational demonstration of CIVAS in the European theater during a winter and early spring season. Perform a study among Army users to assess CIVAS analysis and forecast product value, limitation, and need for improvement.

Resources:

Labor (months): Scientist 2

Programmer 2

Assistant 4

Labor Cost \$37 K

1108 Computer: Available on demand

Other: \$8,000 (Travel and Materials)

Performance Time: 4 Months

Total \$45 K

PHASE III - MEDIUM TERM (6-12 Hrs) DYNAMIC FORECASTING

Task 1 - Formulate Analysis Techniques Suitable for Dynamic Forecasting

Study existing numerical weather prediction output for probable aircraft icing situations. Identify meso scale features lacking in depiction of initial conditions. Assess reasonableness of incorporating microphysical cloud properties within analysis for dynamic predictions. Determine cloud physics characteristics compatible with and contained within a dynamically consistent analysis scheme.

Resources:

Labor (months):	Scientist	1	
	Programmer	2	
	Assistant	2	
	Labor Cost		\$22 K
1108 Computer:	1 Hour		
Other:	None		
Performance Time:	4 Months		
	Total		\$22 K

PHASE III - MEDIUM TERM (6-12 Hrs) DYNAMIC FORECASTING

Task 2 - Combine CIVAS with Macro and Meso-Scale Dynamic Forecast Models

Focus on using available synoptic and meso-scale forecast model outputs. Develop interrelationships between standard forecast models and helicopter icing conditions. Apply CIVAS to dynamic forecast outputs to specify likely aircraft icing events, locations, and intensities.

Resources:

Labor (months): Scientist 6
 Programmer 6
 Assistant 1

Labor Cost \$75 K

1108 Computer: 10 Hours

Other: \$1,000 (Travel)

Performance Time: 12 Months

Total \$76 K

PHASE III - MEDIUM TERM (6-12 Hrs) DYNAMIC FORECASTING

Task 3 - Conduct Experimental Validation Studies

Assemble a data base of weather events, conducive to aircraft icing, produced by objective analyses of actual weather sequences as well as those produced by numerical weather predictions. Collect a corresponding validation data base. Perform a statistical appraisal of medium term dynamic forecast verification.

Resources:

Labor (months): Scientist 1

Programmer 2

Assistant 1

Labor Cost \$19 K

1108 Computer: 5 Hours

Other: None

Performance Time: 3 Months

Total \$19 K

PHASE IV - ICING FORECAST DEMONSTRATION DATA SYSTEM

Task 1 - Prepare Experimental Designs for Field Demonstrations

Consider kinematic and dynamic forecast needs for data collection, assimilation, error checking, and analysis.

Prepare a data sequence design to depict time progressions of aircraft icing events. Give design considerations to assess user likes and dislikes with CIVAS demo output.

Resources:

Labor (months): Scientist 1

Programmer 1

Assistant 0

Labor Cost \$12 K

1108 Computer: None

Other: None

Performance Time 1 Month

Total \$12 K

PHASE IV - ICING FORECAST DEMONSTRATION DATA SYSTEM

Task 2 - Establish Grid Networks and Data Gathering Procedures

Determine area of data influence and boundary conditions on analysis and forecast techniques. Determine trade-offs in defining finite difference grid size from the standpoint of providing dynamic consistency and icing event resolution. Establish weather data collection, error checking, event tagging and assimilation procedures.

Resources:

Labor (months): Scientist 3

Programmer 4

Assistant 4

Labor Cost \$53 K

1108 Computer: 10 Hours

Other: None

Performance Time: 6 Months

Total \$53 K

PHASE IV - ICING FORECAST DEMONSTRATION DATA SYSTEM

Task 1 - Prepare Experimental Designs for Field Demonstrations

Consider kinematic and dynamic forecast needs for data collection, assimilation, error checking, and analysis. Prepare a data sequence design to depict time progressions of aircraft icing events. Give design considerations to assess user likes and dislikes with CIVAS demo output.

Resources:

Labor (months): Scientist 1

Programmer 1

Assistant 0

Labor Cost \$12 K

1108 Computer: None

Other: None

Performance Time 1 Month

Total \$12 K

PHASE IV - ICING FORECAST DEMONSTRATION DATA SYSTEM

Task 2 - Establish Grid Networks and Data Gathering Procedures

Determine area of data influence and boundary conditions on analysis and forecast techniques. Determine trade-offs in defining finite difference grid size from the standpoint of providing dynamic consistency and icing event resolution. Establish weather data collection, error checking, event tagging and assimilation procedures.

Resources:

Labor (months): Scientist 3

Programmer 4

Assistant 4

Labor Cost \$53 K

1108 Computer: 10 Hours

Other: None

Performance Time: 6 Months

Total \$53 K

PHASE IV - ICING FORECAST DEMONSTRATION DATA SYSTEM

Task 3 - Develop Data Base Management System

In addition to routinely measured weather data, consideration will be given to incorporating details provided by such observational tools as weather radar and satellites and such analysis and forecast outputs from the Air Force Global Weather Center. Dynamic management procedures will be developed to establish an array of analyzed and forecast data available to CVAS on the basis of timeliness, representativeness, reliability, and overall value. Consideration will be given to satisfying the data needs of the cloud physics models, synoptic climatology methods, and the analysis and kinematic and dynamic forecast techniques.

Resources:

Labor (months): Scientist 4

Programmer 5

Assistant 2

Labor Cost \$58 K

1108 Computer: 3 Hours

Other: None

Performance Time: 9 Months Total \$58 K

PHASE IV - ICING FORECAST DEMONSTRATION DATA SYSTEM

Task 1 - Complete Computer Graphics Output and Verification Programs

Develop output graphics in black and white, as well as color, methods for real-time CIVAS analysis and forecast depiction. Determine if and how much on-line interaction can be tolerated between user, e.g. helicopter pilot, and CIVAS system. Develop output graphics to depict, upon request, CIVAS output on a remote terminal. Prepare software to correlate CIVAS forecast outputs with corresponding CIVAS analysis to establish technique validation.

Resources:

Labor (months): Scientist 1

Programmer 3

Assistant 0

Labor Cost \$20 K

1108 Computer: 1 Hour

Other: None

Performance Time: 3 Months

Total \$20 K

CIVAS FORECAST PLAN

PROJECTS

TIME AFTER START (MONTHS)

0 3 6 9 12 15 18 21 24 27 30 33 36 39

PHASE I - Cloud Icing Models (\$134.1K)

- T1 - Event Profiles (\$34.5K)
- T2 - Climatology (\$33.1K)
- T3 - Cloud Physics (\$31K)
- T4 - Verify (\$35.5K)

PHASE II - (0-9 hrs.) Nowcasting (\$207K)

- T1 - Kinematic (\$35K)
- T2 - Real Time Nowcasting (\$111K)
- T3 - New Ice Models (\$16K)
- T4 - In Field Demo (\$45K)

PHASE III - (6-12 hrs.) Dynamic Forecasting (\$117K)

- T1 - Dynamic Analysis (\$22K)
- T2 - Dynamic Forecasting (\$76K)
- T3 - Validation (\$19K)

PHASE IV - Forecast Demo Data System (\$143K)

- T1 - Experimental Designs (\$12K)
- T2 - Data Gathering (\$53K)
- T3 - Data Management (\$58K)
- T4 - Graphics Output & Verify (\$20K)

GRAND TOTAL COST (\$601.1K)

3. CIVAS DESCRIPTION

3.1 BACKGROUND

The Cloud Icing and Visibility Analysis System (CIVAS) was developed from the Cloud/Fog Analysis System (CFAS)⁽¹⁾ and the Cloud/Fog Applications Routines (CFAR)⁽²⁾. The function of the CFAS is to create and maintain information on cloud cover, fog and weather in near real-time on a 25 km spaced gridded square measuring 500 km on a side. The geographical location of the gridded square or window is selected by the user. The meteorological data sources that the CFAS was designed to utilize include:

- 1) Selected elements from scheduled teletype network transmissions of surface and upper air observations such as AIRWAYS (Service A), SYNOP (Service C) and RAOB (Service C) messages.
- 2) Three hourly cloud cover prognosis produced by the Air Force Global Weather Central's (AFGWC) Three Dimensional Neph-analysis Model (3D-NEPH).
- 3) Elements of non-scheduled and special weather observations and reports with elements corresponding to those in either of the above sources.

From a collection of the aforementioned observations and reports, the CFAS creates a Cloud/Fog Data Base (CFDB) consisting of fifteen

parameters (described in Table 3.1) at each grid point. The hierarchy of the subprograms constituting the CFAS and their calling sequence are illustrated in Figure 3.1. A brief description of how the CFAS functions follows.

Task commands, operational parameters and the meteorological observations are inputted to the CFAS through Main Program CFMAIN/DSK. The CFAS is initiated with a TASK = 1 command. The initiation which is carried out by Subprogram BEGIN, consists of setting up the directory for the mass storage files that will hold the input data.

Observational data are inputted upon the issuance of a TASK = 2 command. Up to 143 words may be contained in each observation or report. AIRWAYS and SYNOP reports are processed by Subprogram SFDINT, RAOB's by UADINT and AFGWC 3D-NEPH forecast data by AFDINT. The processing performed on the observations, which is referred to as interpretation, consists of the calculation, determination or inference of one, some, or all of the CFDB parameters at the location of each observation from the data contained in that observation alone. The interpreted observations, of 48 words each, are then catalogued and put out to disk files by Subprogram STOREC.

The creation of the CFDB is initiated by a TASK = 3 command. Creation of the CFDB is the analysis at each grid point in the window of the CFDB parameters from all catalogued interpreted observations with

TABLE 3-1

CLOUD/FOG DATA BASE PARAMETERS

<u>Variable Name in CFAS</u>	<u>Description</u>
TCIC	Total sky cover (00-100).
NCEIL	Height ceiling layer, (dekameters, AGL), minus if variable.
NVV	Prevailing visibility at surface, (meters), minus if variable.
MINBAS	Height of base of lowest cloud, (dekameters, AGL).
MAXTOP	Height of top of highest cloud, (dekameters, AGL).
MSPWE	Most significant present weather element (WMO Code 4677).
	Percent cloud cover in the layer from
LCOV(1)	Surface to 45 meters AGL.
LCOV(2)	45 meters AGL to 91 meters AGL.
LCOV(3)	91 meters AGL to 183 meters AGL.
LCOV(4)	183 meters AGL to 305 meters AGL.
LCOV(5)	305 meters AGL to 610 meters AGL.
LCOV(6)	610 meters AGL to 1067 meters AGL.
LCOV(7)	1067 meters AGL to 1524 meters AGL.
LCOV(8)	1524 meters AGL to 1981 meters AGL.
LCOV(9)	1981 meters AGL to 3048 meters AGL.

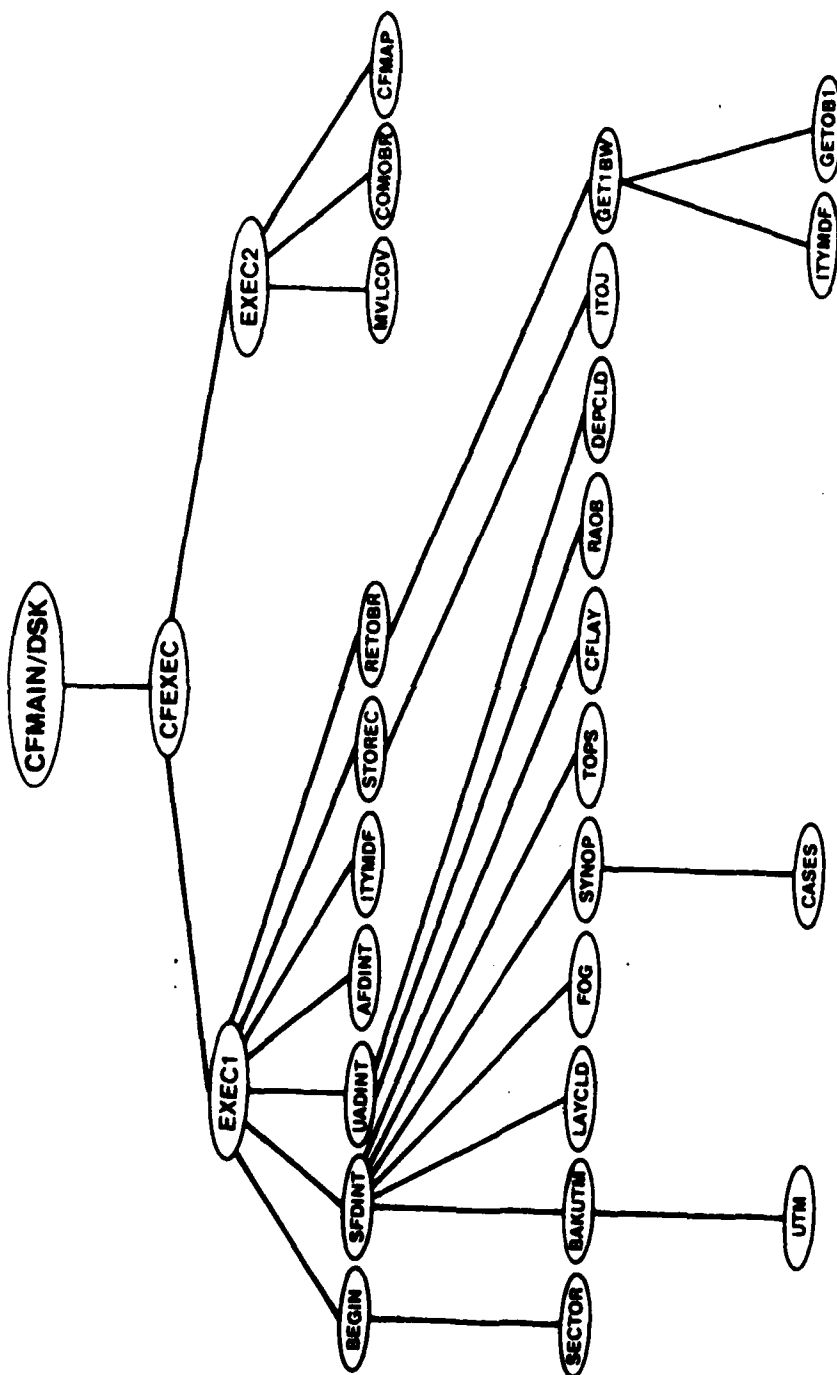


Fig. 3.1 CFAS Subroutines And Calling Sequence

observation or verification times no older than a given time. The qualifying observations are retrieved from mass storage files by Subprogram RETOBR. A determination is made by RETOBR of the most appropriate time and distance constants to be applied to each retrieved observation when it is analyzed. Following the retrieval of all qualified observations, they are combined to form a "best reports" list by Subprogram COMOBR. The formation of best reports involves the combining of complementary information or the resolving of conflicting interpretations among two or more observations close in space and time. The best reports file is the input data to Subprogram CFMAP, which uses an exponential time-distance weighting scheme to analyze the CFDB parameters at the grid points. The newly created CFDB of 6010 words (15 parameters at 400 grid points with a ten-word label) is then output to a disk file.

The Cloud-Fog Application Routines (CFAR) are the means by which the information in the CFDB is presented to the user in a useful manner. This is done through the use of color-coded maps, an example of which is shown in Figure 3.2. A flow diagram of the CFAR is given in Figure 3.3.

Main Program COLOR1 initiates the CFAR. Data statements in COLOR1 specify the parameter ranges and their respective color representations. The CFDB file is read in by Subprogram CFDBRD. The CFDB

parameter values at the grid points are quantified and color-coded in Subprogram CFPREP. Control is then returned to COLOR1 which generates the data to drive the color display.

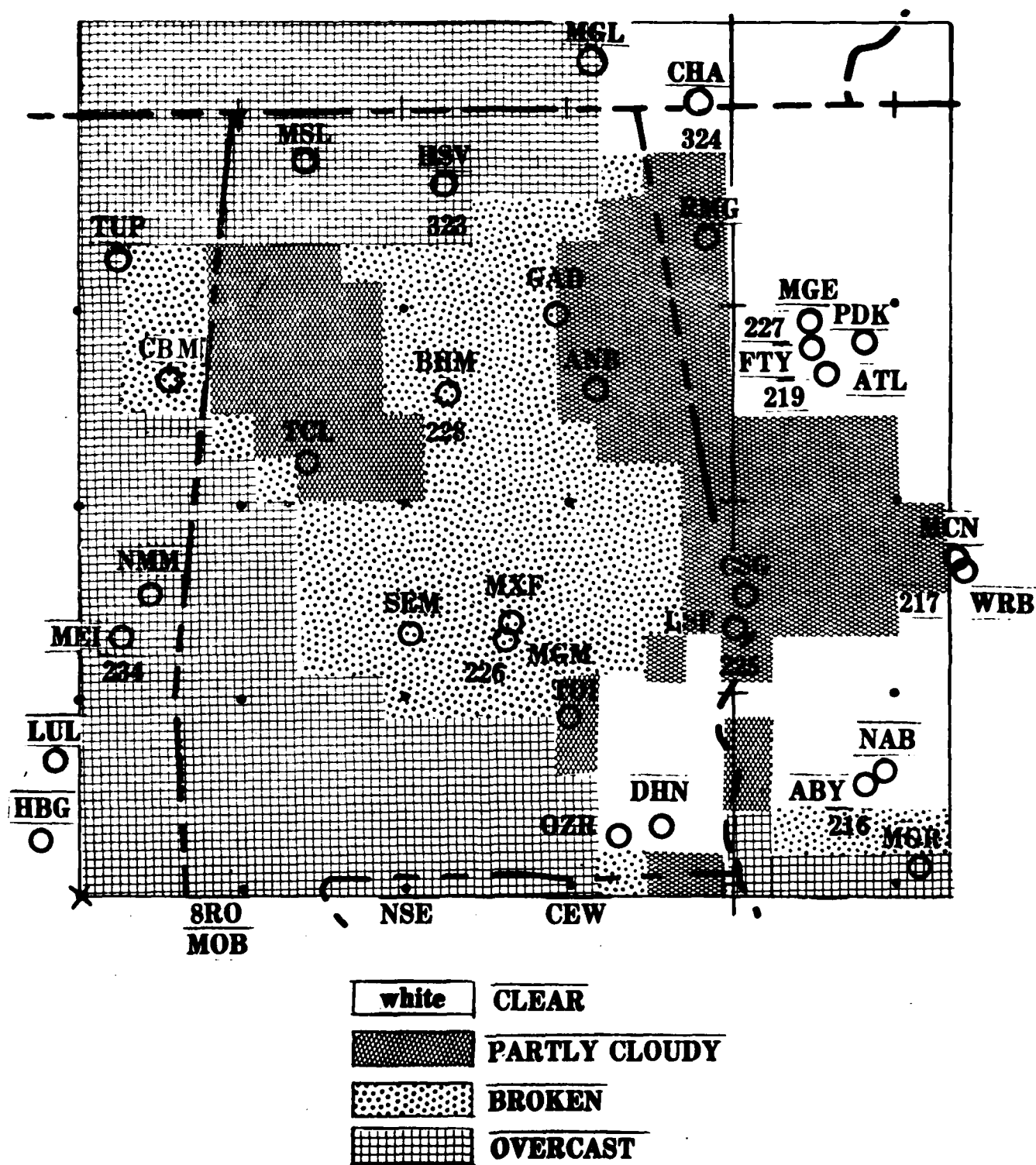


FIG. 3.2 Sky Cover 0340Z 27 Feb 1977 Computer Analysis

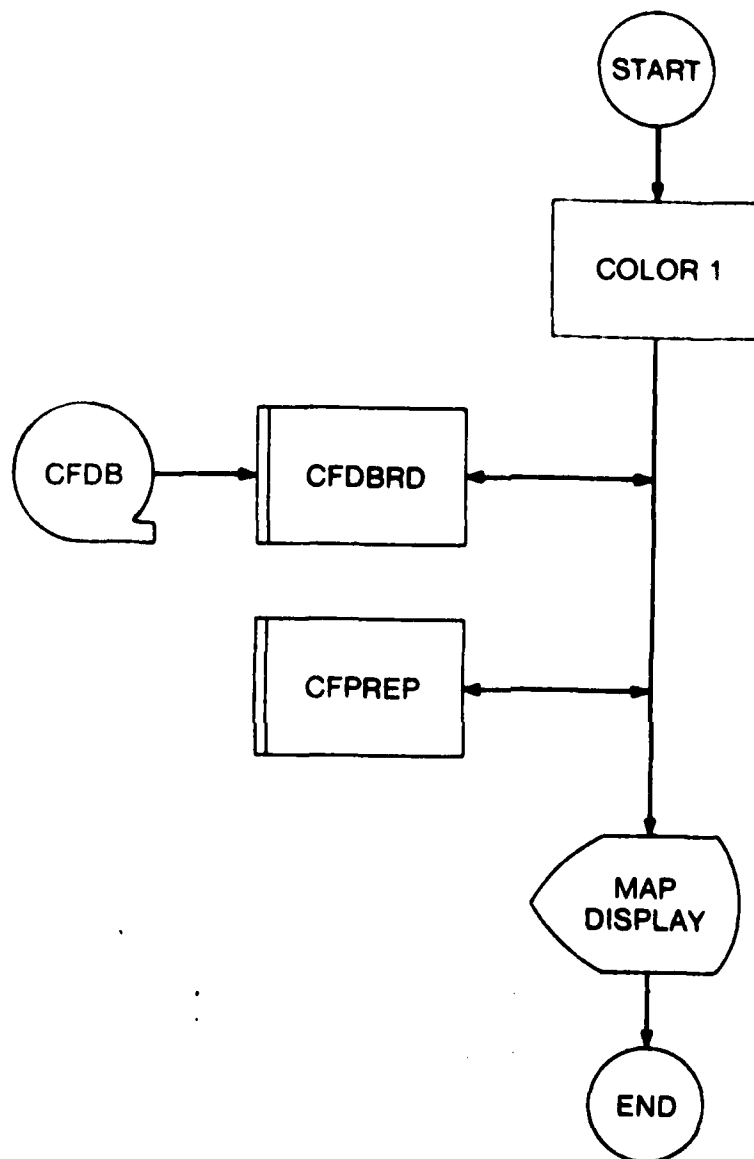


Fig. 3.3 CFAR Color Map Routine

3.2 DEVELOPMENT OF CIVAS FROM CFAS

The development of the CIVAS from the CFAS was accomplished as follows:

- 1) The existing data inputs and outputs of CFAS were assessed to determine the extent to which icing analyses could be produced from the present CFAS.
- 2) A method for determining the probability of icing and the type of icing in each of the nine CFDB layers from information currently available in the CFAS was formulated.
- 3) A two-stage procedure for implementing the icing determination method was designed, coded, tested and incorporated into the CFAS.
- 4) An interpolation procedure for expanding the resolution of the cloud, fog, weather and icing parameters from a 25 km grid spacing to 5 km was designed, coded, tested and incorporated into the CFAS.

The above steps are discussed in more detail in the following subsections.

3.2.1 Icing Information Content in the Existing Input and Output Data of the CFAS

In order for aircraft icing to exist, two necessary conditions must be met. First, a cloud must be present. Second, the cloud must contain super cooled water droplets. The existing CFDB (i.e. Table 3-1) contains information on the presence of clouds in nine terrain following layers. However, there is no information in the existing CFDB that could be used to distinguish between water and ice clouds. On the other hand, among the existing inputs to the CFAS there exists both direct measures of the vertical temperature profile and surface temperatures from which the heights of selected temperature levels could be estimated via the Standard Atmosphere lapse rate. This information can be used to determine if the necessary conditions for a super cooled water droplet cloud exist.

3.2.2 Determination of Probability and Type of Icing

Icing probability and type determinations are based upon the percentage cloud cover, temperature at the base of the cloud and the minimum temperature in the cloud. Implicit in the icing determination method used here is the assumption that if the temperature at the level of the base of the cloud is above freezing and at some level within the the cloud the temperature falls below 0°C , the cloud is assumed to contain super cooled water droplets at levels colder than the 0°C isotherm. This is a broad based criterion for the existence of a super cooled water droplet cloud.

Not accounted for in the above criterion are the detailed micro-physical differences between clouds of differing types, geographical locations and season. The possible effects of those factors on the existence of a super cooled water droplet cloud should be investigated as indicated in the previous sections of this report. Additionally, the criterion for the existence of a super cooled water droplet cloud, as well as the type classification of icing, which is also temperature dependent, consider only the lowest level or first occurrence of the critical temperature levels. The net effect of this is for the vertical extent of the icing regime to be exaggerated and for the type classification to be questionable in the case of temperature inversions occurring within a cloud.

The type of icing that occurs within each of the nine cloud layers is determined by the temperature within the layer. Table 3-2 gives the temperature ranges for the three icing classifications. The temperature at the lower level of the cloud is used as the determinant for the type of icing within the entire layer.

TABLE 3-2

Temperature Range	Icing Type
0°C to 4°C	Clear
-4°C to -15°C	Rime
less than -15°C	Kernel

The probability of icing within a cloud layer is taken to be equal to the per cent cloud cover within the layer.

If the temperature at the base of the lowest cloud is less than 0°C, the cloud is assumed to be composed of only ice particles and thus aircraft icing is assumed not to exist within any of the cloud layers.

3.2.3 Two-Stage Icing Model Implementation

The conversion of the CFAS to CIVAS required a modification of the fundamental procedural structures of the CFAS. For the CFAS, each observation is interpreted, the result of this interpretation being, to the maximum extent permissible from the data in the observation, a value for each of the CFDB parameters. In the subsequent best reports procedure and the analysis itself the number and descriptions of the CFDB parameters are preserved.

The CIVAS on the other hand was found to be more efficiently implemented by dealing with an intermediate set of parameters, the cloud base temperature and heights of the 0°C , -4°C and -15°C levels in the interpretation, best reports and analysis to 25 km grid points stage. Then after interpolation to the 5 km grid point arrays, the actual icing evaluations are made. By proceeding in this manner a considerable saving in time and storage requirements is realized.

A tree diagram showing the calling sequence and hierarchy of subprograms in the CIVAS is given in Figure 3.4. Table 3-3 is a tripartite categorization of the CIVAS subprograms. The first group consists of those subprograms which were unchanged in the conversion of the CFAS to the CIVAS. The second group is composed of subprograms from the CFAS that were modified for the CIVAS. The third group of subprograms were newly created for the CIVAS. The description of the CIVAS

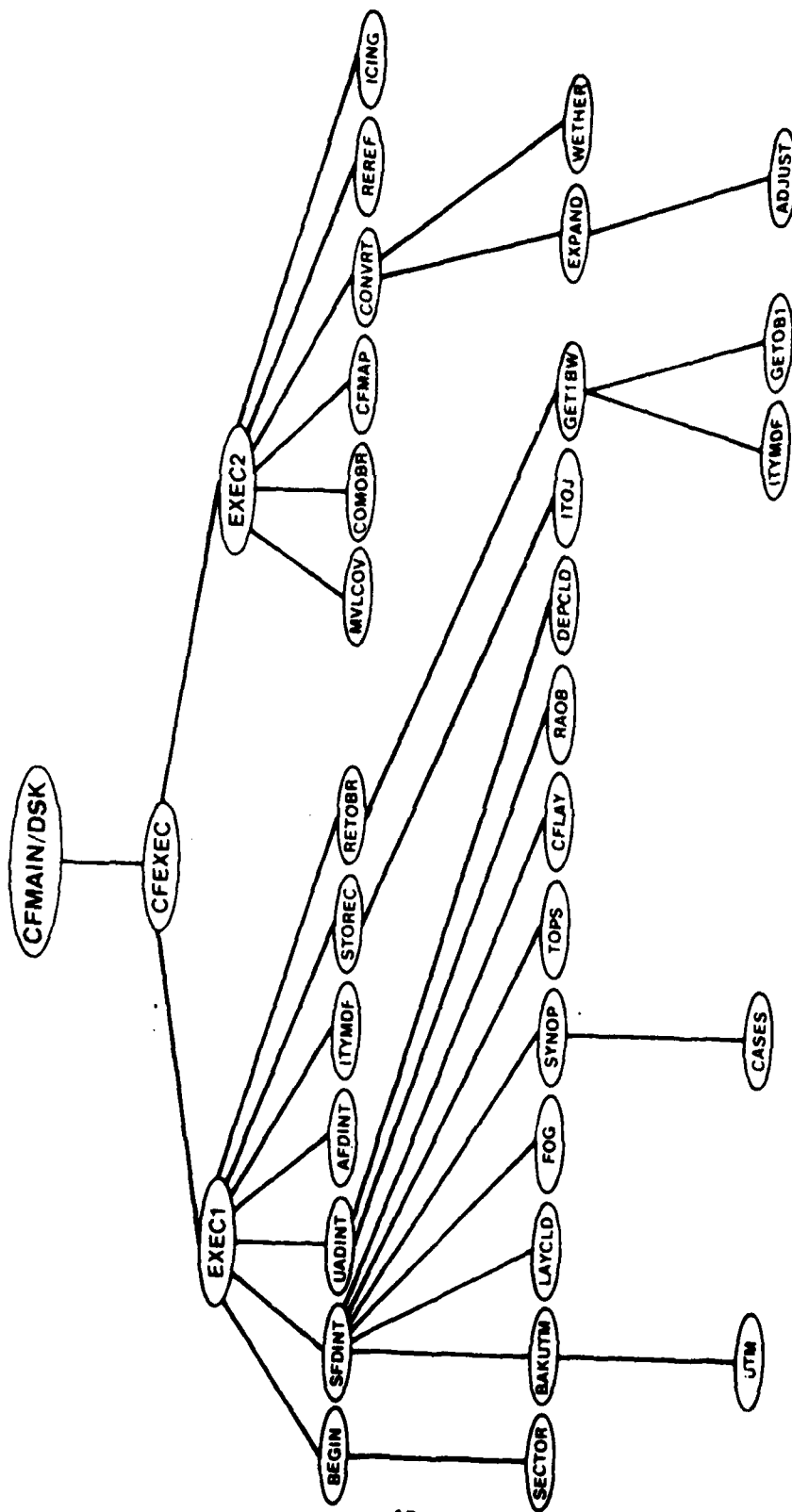


Fig. 3.4 File Control For CIVAS

will concentrate on the procedural modifications that were made in the second category of subprograms in Table 3-3, as well as the subprograms newly created for the CIVAS.

Table 3-3

CIVAS SUBPROGRAMS

<u>Unmodified CFAS Subprograms</u>	<u>Modified CFAS Subprogram</u>	<u>New Subprograms</u>
. AFDINT	. BASE	. ADJUST
. BAKUTM	. BEGIN	. CONVRT
. BLKIN/DSK	. CFMAIN/DSK	. EXPAND
. BLKOUT/DSK	. CFMAP	. ICING
. CASES	. COMOBR	. REREF
. CFEXEC	. EXEC1	. WETHER
. CFLAY	. EXEC2	
. DEPCLD	. RAOB	
. FOG	. RETOBR	
. GETOBI	. SFDINT	
. GETIBW	. UADINT	
. ITOJ		
. ITYMOF		
. LAYCLD		
. MVLCOV		
. NOSECT		
. SECTOR		
. STOREC		
. SYNOP		
. TOPS		
. UTM		

The first stage procedures of the CIVAS produce the nineteen parameter Augmented Cloud/Fog Data Base which is described in Table 3-4. The icing parameters, Z000I, ZM04I, ZM15I and TEMBC are determined in subprogram SFDINT by extrapolation of the reported surface temperature at the standard atmosphere lapse rate of -6.44°C/km . In subprogram UADINT these parameters are determined by interpolation of the observed RAOB data. The latter determination (i.e. by interpolation of RAOB data) is much preferred from the standpoint of accuracy. Unfortunately, however, the density and frequency of RAOB reports are very sparse in comparison to the 25 km grid spacing of the augmented CFDB even in a data rich region such as the southeastern U.S.A.

The second stage of the CIVAS icing analysis is implemented following the 25 km to 5 km resolution expansion. The resolution expansion results in these being 100 by 100 or 10,000 grid points for the 500 km square window. With nineteen parameters per grid point, the augmented CFDB requires 190,000 words of storage. The expanded augmented CFDB is created and written to a disk file one parameter at a time. Upon completion of the expanded augmented CFDB, the four icing parameters are read back into the program. The layered cloud cover parameters are then read in one layer at a time, the icing probability and type in the layer is determined, coded as a single word for each grid point and output as a 10,000 word record to the disk. Following the icing determination, the CIVAS data base contains an additional 90,000 parameters over and above the 190,000 of the expanded augmented CFDB. The icing parameter for

TABLE 3-4
AUGMENTED CLOUD/FOG DATA BASE PARAMETERS

<u>Variable Name</u> <u>in CIVAS</u>	<u>Description</u>
NTCLC	Total sky cover (00-100).
NCEIL	Height ceiling layer, (dekameters, AGL), minus if variable.
NVV	Prevailing visibility at surface, (meters), minus if variable.
MINBAS	Height of base of lowest cloud, (dekameters, AGL).
MAXTOP	Height of top of highest cloud, (dekameters, AGL).
MSPWE	Most significant present weather element (WMO Code 4677). Percent cloud cover in the layer from
LCOV(1)	Surface to 45 meters AGL.
LCOV(2)	45 meters AGL to 91 meters AGL.
LCOV(3)	91 meters AGL to 183 meters AGL.
LCOV(4)	183 meters AGL to 305 meters AGL.
LCOV(5)	305 meters AGL to 610 meters AGL.
LCOV(6)	610 meters AGL to 1067 meters AGL.
LCOV(7)	1067 meters AGL to 1524 meters AGL.
LCOV(8)	1524 meters AGL to 1981 meters AGL.
LCOV(9)	1981 meters AGL to 3048 meters AGL.
Z000I	Height of the 0° C Isotherm, (meters, AGL)
ZM04I	Height of the -4° C Isotherm, (meters, AGL)
ZM15I	Height of the -15° C Isotherm, (meters, AGL)
TEMBC	Temperature at the base of lowest cloud, (°K)

each of the nine layers is a three digit number coded as shown in Table 3-5.

Table 3-5		
ICING PARAMETER CODE		
<u>Icing Code</u>	<u>Icing Type</u>	<u>Probability of Icing</u>
00 to 100	CLEAR	00 to 100
200 to 300	RIME	00 to 100
400 to 500	KERNEL	00 to 100

3.2.4 Five Kilometer Grid Interpolation

Interpolation from 20 by 20, 25 km grid-squares, to 100 by 100, 5 km grid-squares is accomplished by averaging radially outward from the center of the square to the perimeter of the squares. Or, visualized differently, interpolation can be thought of as taking place in 4 quadrants about the center, Figure 3-5. This quadrant structure is necessary to minimize the impact of discontinuous values (an infinite ceiling, for example), providing a significant advantage over a straight linear interpolation done on the entire grid-square.

Using quadrant 1 as an example, the following example illustrates how the interpolation procedures is implemented. First the interpolation is done between the perimeter values NORTH and WEST (in this case), and the CENTER value giving:

$$\begin{aligned}N1 &= (\text{NORTH}-\text{CENTER})/3 \\N2 &= 2*N1 \\W1 &= (\text{WEST}-\text{CENTER})/3 \\W2 &= 2*W1\end{aligned}$$

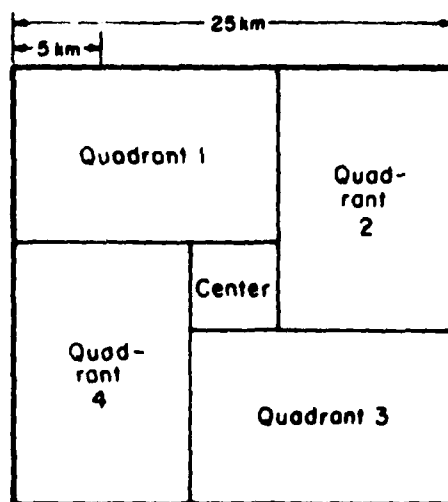


Fig. 3.5 A 25 KM grid-square is broken into 4 quadrants for interpolation into 25, 5 KM Grid-squares.

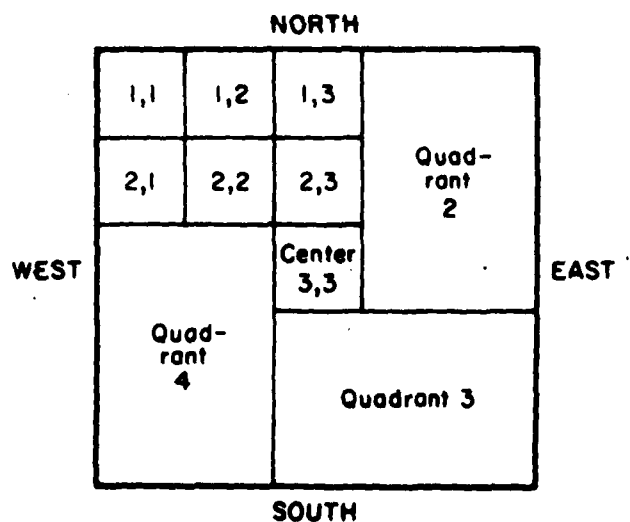


Fig. 3.6 Row and column numbers for 5 KM grid squares

(Where NORTH and WEST are the values measured in the 25 KM grid-squares north and west of the square being interpolated. CENTER is the value, on a 25 KM basis, of the grid-square being interpolated).

These values are then used to modify CENTER as follows: (See Fig. 3.6)

$$\begin{array}{lll} 5 \text{ KM}(1,1) & = & \text{CENTER} + (\text{N2}+\text{W2})/2 \\ 5 \text{ KM}(1,2) & = & \text{CENTER} + (\text{N2}+\text{W1})/2 \\ 5 \text{ KM}(1,3) & = & \text{CENTER} + \text{N2} \\ 5 \text{ KM}(2,1) & = & \text{CENTER} + (\text{N1}+\text{W2})/2 \\ 5 \text{ KM}(2,2) & = & \text{CENTER} + (\text{N1}+\text{W1})/2 \\ 5 \text{ KM}(2,3) & = & \text{CENTER} + \text{N1} \end{array}$$

The center value, 5 KM(3,3), always remains the 25 KM center value CENTER.

Missing perimeter values are reset to equal CENTER, removing their influence on the interpolation. Using the above example, if NORTH were missing it would be set equal to CENTER forcing N1 and N2 to be zero, removing only NORTH influence. It would be erroneous to assume any other NORTH value on the basis that CENTER is the average of the perimeter values. This would not reflect certain discontinuous situations, such as an infinite ceiling reported as missing. These are weather observing and reporting problems that cannot be addressed here. This approach provides a conservative analysis which may extend a cloud or icing condition for an additional 5 KM grid interval. Thus when a data uncertainty exists, this approach fosters aircraft safety by emphasizing the existence of clouds and icing. Additional attention should be given to this problem and tests should be conducted before going operational with CIVAS.

4. DESCRIPTION OF CIVAS PROGRAMS

4.1 CFAS SUBROUTINES MODIFIED FOR CIVAS

4.1.1 Subprogram BASE

The dimension of arrays IBUF and JBUF were increased from 2200 to 2400 and 528 to 576, respectively, in order to accommodate the larger size of the interpreted CIVAS observations.

4.1.2 Subprogram BEGIN

The number of words per record, NWDREC, was increased from 44 to 48 to accommodate the longer CIVAS record length.

4.1.3 Main Program CFMAIN/DSK

Several input/output and format statements, as well as data string and array lengths were changed to provide for the printing of the longer CIVAS interpreted observations and the icing data augmented CFDB.

4.1.4 Subprogram CFMAP

Modifications to executable statements, as well as to array dimensions were required in CFMAP to accommodate the analyses of the icing dependent temperature levels and temperature at the base of the cloud, as well as the original CFDB parameters.

The analysis procedure employed in CFMAP requires slightly differing processing among the various types of parameters in the CFDB. In this regard, the icing parameters are processed in a manner similar to those used on the heights of the minimum base and highest top of the clouds.

4.1.5 Subprogram COMOBR

Numerous modifications to the executable code, as well as the specification statements was required in COMOBR to provide for the addition of the icing parameters. None of the modifications altered, deleted or amended the procedural concepts in COMOBR.

4.1.6 Subprogram EXEC1

Modifications were required to a relatively few executable, format and specification statements. No procedural concepts were altered, amended or deleted.

4.1.7 Subprogram EXEC2

EXEC2 was the most significantly impacted element of the CFAS in the conversion to the CIVAS. Numerous modifications had to be made to the executable as well as the specification code. The analysis procedures used in the CFAS version of EXEC2 were amended to include the four additional icing parameters of the

augmented CFDB. Most significant of the modifications to EXEC2 were those to the procedural concepts. Within the CIVAS EXEC2 the several routines, i.e. CONVRT, EXPAND, ADJUST, WETHER and REREF, which increase the horizontal resolution of the augmented CFDB from 25 km to 5 km are employed. And finally within the CIVAS EXEC2 the augmented CFDB is converted to the final CIVAS data base in which the probability and type of icing is actually specified.

4.1.8 Subprogram RAOB

The executable code in RAOB was amended to provide for the calculation and transfer to UADINT of a completely interpolated temperature vs. height profile.

4.1.9 Subprogram RETOBR

Modifications to the specification and executable code of RETOBR were necessary to permit the retrieval of the longer CIVAS interpreted observations. No procedural concepts were altered, amended or deleted.

4.1.10 Subprogram SFDINT

The specification and executable code of SFDINT was amended to include the calculation of the icing parameters. For non missing surface temperature, ITT, the heights of the 0° C, -4° C and -15° C isotherms, Z000I, ZM04I, and ZM15I, respectively, and the temperature at the base of the lowest cloud, TEMBC, are given by the following expressions

```
Z000I = IFIX ((-273. - FLOAT(ITT))/6.44)*1000.)  
ZM04I = IFIX ((-269. - FLOAT(ITT))/6.44)*1000.)  
ZM15I = IFIX ((-258. - FLOAT(ITT))/6.44)*1000.)  
TEMBC = IFIX (FLOAT(ITT) -.0644*FLOAT(MINBAS))
```

where MINBAS = base height of lowest cloud (dekameters)

If the surface temperature is missing all icing parameters are set equal to missing.

4.1.11 Subprogram UADINT

The specification and executable code of UADINT was amended to include the calculation of the icing parameters. A radiosonde temperature vs. height profile with observed or calculated heights at each mandatory and significant level is passed to UADINT from RAOB. The profile is scanned and the first level below each of the icing significant levels, i.e. 0° C, -4° C and -15° C isotherms, and the base of the lowest cloud are identified. A linear interpolation between these levels and the next higher ones is used to determine the heights of the 0° C, -4° C and -15° C isotherms and the temperature at the base of the lowest cloud. If the base of the lowest cloud is missing, the temperature at the base of the cloud is set equal to missing. Also, if any of the icing significant levels are not reached within the maximum height of the CIVAS cloud layers (i.e. 3040 meters AGL), the heights of these levels are set equal to missing.

4.2 NEWLY CREATED ROUTINES FOR CIVAS

4.2.1 Subroutine ADJUST

Input

CENTER -- Analyzed values for the 25 KM square currently being EXPANDED. (See write up under subroutine EXPAND)
NORTH -- Analyzed value for the 25 KM square North of CENTER.
SOUTH -- Analyzed value for the 25 KM square South of CENTER.
EAST -- Analyzed value for the 25 KM square East of CENTER
WEST -- Analyzed value for the 25 KM square West of CENTER.

Output

Any and all of the perimeter variables NORTH, SOUTH, EAST, and WEST may be changed to insure validity.

Description and Documentation

Subroutine ADJUST alters the perimeter variables NORTH, SOUTH, EAST, and WEST such that they are all valid, or all missing.

Missing perimeter values are validated by assuming a value such that the average:

$$\text{CENTER} = \frac{\text{NORTH} + \text{SOUTH} + \text{EAST} + \text{WEST}}{4}$$

is preserved. If more than 2 perimeter conditions are missing, all perimeter variables are set to missing. This forces subroutine EXPAND to set all interpolated values of the currently EXPANDING grid-square to missing.

4.2.2 Subroutine CONVRT

Common

OLDGRD -- The "Input" grid of 20 by 20, 25 KM grid squares
NEWGRD -- The "Output" grid of 100 by 100, 5 KM grid squares.

Description and Documentation

Subroutine CONVRT converts the analyzed data-base of 20 x 20,

25 KM grid-squares into 100 by 100, 5 KM grid-squares for each of the 19 parameters. This "Expanded" array (NEWGRD) is then written to disk (Unit 20) with each parameter treated as an unformatted "Record" of 10,000 words in length.

CONVRT itself is concerned with defining the perimeter conditions: NORTH, SOUTH, EAST, WEST, and then calls EXPAND or WETHER, where the actual interpolation is done and stored in NEWGRD.

4.2.3 Subroutine EXPAND

Input

ROW -- Current row (on the 20 by 20, 25 KM basis) to
 be EXPANDED.

COL -- Current column (on the 20 by 20, 25 KM basis)
 to be EXPANDED.

CENTER -- Analyzed value for the 25 KM square as defined
 by ROW, COL.

NORTH -- Analyzed value for the 25 KM square as defined
 by (ROW-1), COL.

SOUTH -- Analyzed value for the 25 KM square as defined
 by (ROW+1), COL.

EAST -- Analyzed value for the 25 KM square as defined
 by ROW, (COL+1).

WEST -- Analyzed value for the 25 KM square as defined
 by ROW, (COL-1).

Common

NEWGRD -- The EXPANDED grid of 100 by 100, 5 KM grid-
 squares

Description and Documentation

Subroutine EXPAND interpolates 1, 25 by 25 KM grid-square (as defined by ROW, COL), into 25, 5 by 5 KM grid-squares; inserting the new values into NEWGRD. The NEWGRD interpolated values are a distance-weighted average of the perimeter values NORTH, SOUTH, EAST, and WEST. (For a further discussion see section 3.2.4.) It is important not to confuse the 2 grids: for, though the 2 grids represent the same geographical location, the scale is different by a factor of 5. Figure 3.7 shows the current grid to be EXPANDED, CENTER, and the surrounding grid-squares whose values are NORTH, SOUTH, EAST, and WEST.

4.2.4 Subroutine ICING

Input

(Disk file on unit 20 containing the icing parameter on a 5 KM basis, referenced to above ground level.)

Description and Documentation

Subroutine ICING produces the probability and type of icing for each 5 KM grid-square at each of the 9 cloud layer levels. Type of icing is determined by the temperature at that level:

0 to -4 degrees celsius = CLEAR icing,

-4 to -15 degrees celsius = RIME icing,

less than -15 degrees celsius = KERNEL icing.

Probability is the percent sky-cover at that grid-square and layer.

NOTE:

If the cloud base temperature is colder than zero degrees celsius, it is assumed icing will not occur; the cloud is

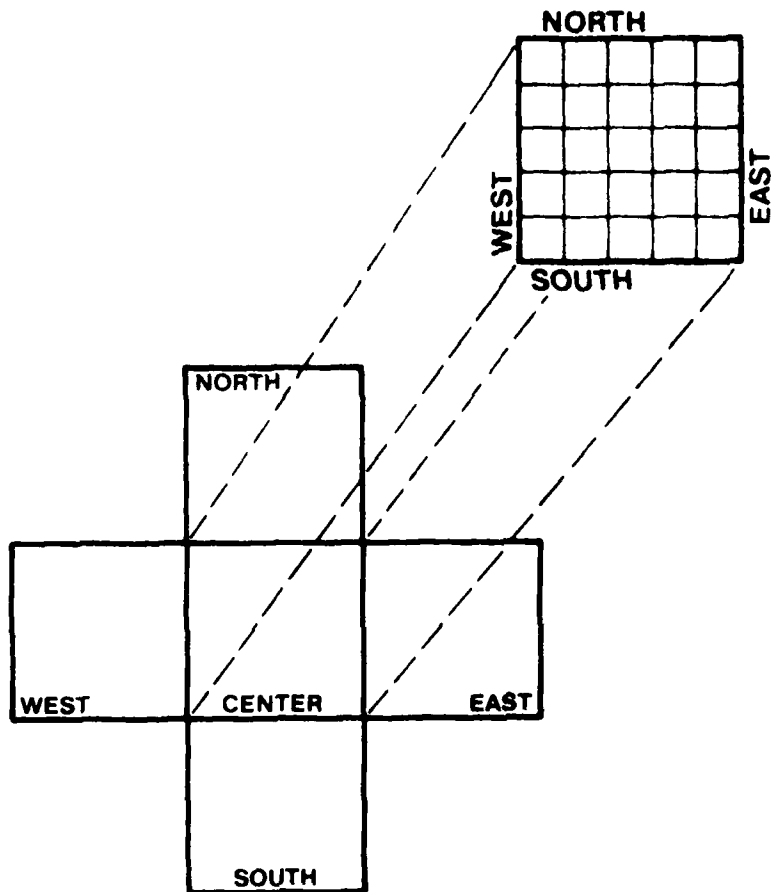


Fig. 3.7 Expansion of CENTER Square to Twenty Five 5 km. Grid Squares.

already frozen, and thus no supercooled droplets exist to form aircraft icing.

4.2.5 Subroutine LSTMAP

Input

CIVASP = CIVAS Parameter number, 1 to 24

<u>Parameter No.</u>	<u>Parameter Description</u>
1	Total skycover
2	Ceiling height
3	Visibility
4	Base of lowest cloud
5	Top of highest cloud
6	Present weather
7 to 15	Cloud Cover in layer 1 to 9
16 to 24	Icing in layer 1 to 9

SUBWIN = I, J indices of subwindow

1,5	2,5	3,5	4,5	5,5	100 km 500 km
1,4	2,4	3,4	4,4	5,4	
1,3	2,3	3,3	4,3	5,3	
1,2	2,2	3,2	4,2	5,2	
1,1	2,1	3,1	4,1	5,1	

Description and Documentation

Main program LSTMAP outputs via the line printer in the form of a 20 by 20 word array, the values of the user selected CIVAS parameter for the selected sub-window. Missing values show as "*****".

4.2.6 Subroutine REREF

Input

IHREF -- The altitude reference point determined in EXEC1.
(Disk file on unit 20 containing the parameters to be referenced on a 5 KM basis).

Description and Documentation

Subroutine REREF rereferences the 5 KM interpolated parameters to their above ground level heights. Only parameters sensitive to height are rereferenced: Total Skycover, for example, is the same regardless of reference height. The 15 parameters rereferenced are: Ceiling, Cloud Base, Cloud Top, the 9 Cloud Layers, and the heights of the 0, -4, and -15 degrees celsius isotherms. These parameters are read in from disk (Unit 20), rereferenced via a table of interpolated ground levels, and written back to disk.

4.2.7 Subroutine WETHER

Common

OLDGRD -- The "Input" grid of 20 by 20, 25 KM grid-squares
NEWGRD -- The "Output" grid of 100 by 100, 5 KM grid-squares

Description and Documentation

As present weather is a non-linear parameter, an algebraic interpolation is not possible. Therefore WETHER, in expanding 1, 25 KM grid-square, into 25, 5 KM grid-squares, selects the nearest present weather. In the case of equidistant present weathers, the worst (highest valued) case is chosen.

5. REFERENCE

1. Fow, B.R. and Mount, W.D., "Development of Cloud/Fog Analysis and Application Subroutines for Experimental Prototype Automatic Meteorological System (EPAMS)", Final Technical Report Contract No. DAAD07-74-C-0251 (1975).

Fow, B.R. and Mount, W.D., "Development of Cloud/Fog Applications Routines for Use with the Automatic Meteorological System", Interim Technical Report Contract No. DAEA-76-C-0060 (1977).

6. CIVAS PROGRAM LISTING

If desired, program listings may be obtained from Mr. Harry Maynard at the following address:

Commander/Director
US Army Atmospheric Sciences Laboratory
ATTN: DELAS-BE-0 (Mr. Harry Maynard)
White Sands Missile Range, NM 88002